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# Quantification of soft tissue artefact in motion analysis by combining 3D fluoroscopy and stereophotogrammetry: a study on two subjects

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## Abstract

**Background.** Soft tissue artefact is the most invalidating source of error in human motion analysis using optoelectronic stereophotogrammetry. It is caused by the erroneous assumption that markers attached to the skin surface are rigidly connected to the underlying bones. The quantification of this artefact in three dimensions and the knowledge of how it propagates to relevant joint angles is necessary for the interpretation of gait analysis data.

**Methods.** Two subjects, treated by total knee replacement, underwent data acquisition simultaneously with fluoroscopy and stereophotogrammetry during stair climbing, step up/down, sit-to-stand/stand-to-sit, and extension against gravity. The reference 3D kinematics of the femur and tibia was reconstructed from fluoroscopy-based tracking of the relevant prosthesis components. Soft tissue artefact was quantified as the motion of a grid of retro-reflecting markers attached to the thigh and shank with respect to the underlying bones, tracked by optoelectronic stereophotogrammetry. The propagation of soft tissue artefact to knee rotations was also calculated.

**Findings.** The standard deviation of skin marker trajectory in the corresponding prosthesis-embedded anatomical frame was found up to 31 mm for the thigh and up to 21 mm for the shank. The ab/adduction and internal/external rotation angles were the most affected by soft tissue artefact propagation, with root mean square errors up to 192% and 117% of the corresponding range, respectively.

**Interpretations.** In both the analysed subjects the proximal thigh showed the largest soft tissue artefact. This is subject- and task-specific. However, larger artefact does not necessarily produce larger propagated error on knee rotations. Propagated errors were extremely critical on ab/adduction and internal/external rotation. These large errors can nullify the usefulness of these variables in the clinical interpretation of gait analysis.

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**Keywords:** Human motion analysis; Soft tissue artefact; Knee kinematics; Fluoroscopy; Stereophotogrammetry

## 1. Introduction

The description of human joint kinematics during daily living activity is the main aim of human motion analysis. Stereophotogrammetry allows for the reconstruction of the trajectories of markers or fixtures, on

which markers are mounted, attached to the skin surface of the body segments to be analysed. These trajectories are used to calculate the pose of the underlying bony segments, with the erroneous assumption that markers and bony segments are rigidly connected. It is well known that markers on the surface of the body move with respect to the underlying bones because of the interposition of soft tissues. This interposition is the origin of two different sources of error: anatomical

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